

Claims

[1] A piezoelectric ceramic composition characterized by containing:

metallic element K;

metallic element Na;

metallic element Nb;

M1, which represents a divalent metallic element, or a metallic element combination formally equivalent to a divalent metallic element;

M2, which represents a tetravalent metallic element, or a metallic element combination formally equivalent to a tetravalent metallic element;

M3, which represents a metallic element of a sintering aid component; and

non-metallic element O, wherein, when K, Na, Nb, M1, and M2 constitute the formula $[(1/2)aK_2O - (1/2)bNa_2O - cM1O - (1/2)dNb_2O_5 - eM2O_2]$, a, b, c, d, and e in the formula satisfy the following relations:

$$0 < a < 0.5,$$

$$0 < b < 0.5,$$

$$0 < c < 0.11,$$

$$0.4 < d < 0.56,$$

$$0 < e < 0.12,$$

$$0.4 < a + b + c \leq 0.5, \text{ and}$$

$a + b + c + d + e = 1$; and when the total amount of K, Na, Nb, M1, and M2 as reduced to corresponding oxides is 100

parts by mass, the amount of M3 as reduced to M3 oxide is 5 parts by mass or less.

[2] A piezoelectric ceramic composition as described in claim 1, wherein, when the total amount of K, Na, Nb, M1, and M2 as reduced to corresponding oxides is 100 parts by mass, the amount of M3 as reduced to M3 oxide is 0.1 parts by mass or less.

[3] A piezoelectric ceramic composition as described in claim 1 or 2, wherein M1 is at least one of Ca, Sr, Ba, $(\text{Bi}_{0.5}\text{Na}_{0.5})$, and $(\text{Bi}_{0.5}\text{K}_{0.5})$.

[4] A piezoelectric ceramic composition as described in any of claims 1 through 3, wherein M2 is at least one of Ti, Zr, and Sn.

[5] A piezoelectric ceramic composition as described in any of claims 1 through 4, wherein M3 is at least one of Fe, Co, Ni, Mg, Zn, and Cu.

[6] A piezoelectric ceramic composition as described in any of claims 1 through 5, wherein M3 is a combination of Cu and at least one of Fe, Co, Ni, Mg, and Zn.

[7] A piezoelectric ceramic composition as described in any of claims 1 through 6, wherein a, b, and d in the formula satisfy the following relation: $(a + b)/d \leq 1.00$.

[8] A piezoelectric ceramic composition as described in any of claims 1 through 7, wherein a, b, and c in the formula satisfy the following relation: $0 < c/(a + b + c) \leq 0.20$.

[9] A piezoelectric ceramic composition as described in any of claims 1 through 8, which contains, in addition to K,

Na, Nb, M1, M2, and M3, metallic element Li, wherein at least one of K and Na in the formula is partially substituted by Li.

[10] A piezoelectric ceramic composition as described in any of claims 1 through 9, which contains, in addition to K, Na, Nb, M1, M2, and M3, metallic element Ta, wherein Nb in the formula is partially substituted by Ta.

[11] A piezoelectric ceramic composition as described in any of claims 1 through 9, which contains, in addition to K, Na, Nb, M1, M2, and M3, metallic element Sb, wherein Nb in the formula is partially substituted by Sb.

[12] A piezoelectric ceramic composition as described in any of claims 1 through 11, which has a perovskite crystal structure.

[13] A piezoelectric ceramic composition as described in claim 12, wherein perovskite crystals belong to an orthorhombic system.

[14] A piezoelectric element characterized by comprising a piezoelectric member formed of a piezoelectric ceramic composition as recited in any of claims 1 through 13; and at least a pair of electrodes which are in contact with the piezoelectric member.